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Abstract

Arrow's disclosure paradox implies that information that is not afforded legal protection cannot be bought or sold on the market. This paper emphasizes the important relationship between the paradox of disclosure and the boundaries of the firm question. Only legally protected inventions, i.e., patented inventions, may be traded; pre-patent stages of the innovation process may not. Consequently, by force of law, rather than by the guidance of economic principle, pre-patent innovation must be carried out within the boundaries of a single firm.

Keywords: Boundaries of the firm, disclosure paradox, intellectual property law.

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1. Introduction

Innovation is crucial in technology intensive markets. For many firms inventions are a critical factor of production. Examples of downstream firms purchasing or licensing technology from upstream innovators are common (see, e.g., Arora et al., 2001). Indeed, both Transaction Costs Economics (TCE) and the Property Rights Theory (PRT) suggest that in many cases, efficiency requires that the inventive process—from the conception of an idea through its development and ultimate commercialization—be divided among several firms (Williamson, 1975; Aghion and Tirole, 1994; Arora et al., 2001; Arora and Merges, 2004).

The question thus becomes which stages of the inventive process should be integrated in a single firm and which should be divided among different firms and traded on the market? We argue that the theoretic investigation of the optimal boundary between firm and market cannot be carried out in a legal vacuum. Ideally, only the economic considerations identified by TCE and PRT should affect the "make or buy" decision. In practice, however, law imposes an important constraint on the economic balance between firms and markets.

Critically, the law defines which stages of the inventive process are amenable to market trading. As Arrow (1962) recognized, information that is not afforded legal protection cannot be bought or sold on the market. Absent legal protection, the information holder is in a bind: in order to sell the information, she must disclose it to the potential buyer, but once she does, she has nothing left to sell. This paper emphasizes the important relationship between Arrow's *paradox of disclosure* and the question of the boundaries of information intensive firms. Only legally protected inventions, i.e., patented inventions, may be traded; pre-patent stages of the innovation process may not. Consequently, by force of law, rather than by the guidance of economic principle, pre-patent innovation must be carried out within the boundaries of a single firm.

Intellectual property law is therefore an important factor influencing the boundary between the firm and the market. When it is more difficult to obtain a patent more innovative activity must be integrated within a single firm (or be forgone altogether).

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Conversely, when the legal requirements of patentability are relaxed, as they have been in recent years, a shift of activity from firms to the market should be expected. Trade secret law and the legal treatment of covenants not to compete similarly affect firm boundaries by determining the allocation of entitlements between firms and employees.

The implications of innovation for the make-or-buy decision have been highlighted by Williamson (1975), Teece (1986, 1988), and Aghion and Tirole (1994). Previous work has also recognized the relevance of appropriability and intellectual property law to various contractual, strategic and organizational questions in technology-intensive industries. The importance of appropriability and the relationship between appropriability and intellectual property rights was first emphasized by Teece (1986). Arora et al. (2001) highlight the difficulty in contracting over tacit knowledge and know-how (ch. 5), noting "the role of patents in facilitating transactions in technology." (p. 262) Gans and Stern (2003a) consider the implications of the disclosure paradox for an entrepreneur's choice of a commercialization strategy, recognizing the role of intellectual property in solving the paradox. In a couple of related empirical studies, these authors show how intellectual property rights and appropriability problems affect the timing of cooperation/licensing (Gans and Stern, 2003b) as well as the choice of a start-up innovator between competition or cooperation (i.e. contracting) with more established firms (Gans et al., 2000). Another recent empirical study shows that technologies developed by firms operating in countries with weak intellectual property rights are used more internally (Zhao, 2003). Anton and Yao, in a series of papers, explore the implications of and the strategic responses to the disclosure paradox, caused by imperfect legal protection of pre-patent ideas (Anton and Yao, 1994, 2000, 2001, 2003a, 2003b; see also Bhattacharya and Guriev, 2004).

Finally, Dan Burk and Ashish Arora and Robert Merges, in two recent contributions, explicitly focus on the interrelations between intellectual property law and the boundaries of the firm question. Burk (2004) focuses on the implications of the theory of the firm for intellectual property law. While we focus on the reverse implications of intellectual property law for the theory of the firm, Burk's insights are clearly important for our analysis. Arora and Merges (2004) show that stronger intellectual property rights support smaller firms that specialize in the supply of technology inputs. The analysis in Arora and Merges (2004) can be interpreted as proposing one way to minimize the costs associated with the disclosure paradox—through intellectual property rights in *complementary* assets (see also Merges, 2000; Arora et al., 2001). Our focus, on the other hand, is on intellectual property rights in the core informational asset. More generally, while the literature has focused on the strength of intellectual property rights, we focus on the preconditions for the creation of legally enforceable intellectual property rights.

The remainder of the paper is organized as follows. Section 2 presents a simple model, formalizing the role of intellectual property law as a constraint on the optimal level of vertical integration in technology-intensive industries. Section 3 draws the broader implications of the model for the structure and organization of technology-intensive industries, discussing firm size, the role of research universities, R&D alliances and joint ventures, and R&D financing. Section 4 argues that intellectual property law affects not only the feasibility of the market option but also the feasibility of the firm option. Section 5 concludes.

2. Model

We formalize the effect of intellectual property law on the boundaries of the firm question using a simple PRT model.[1] Consider an inventor (I) and a developer (D). An innovation process combining the efforts of both I and D produces a value $V(i,d)$, where i denotes I's investment and d denotes D's investment. The value of I's outside option is $v^I(i)$, and the value of D's outside option is $v^D(d)$. Assuming $V(i,d) > v^I(i) + v^D(d)$, the first-best investment levels are given by $\max_{i,d}\langle V(i,d) - i - d\rangle$.

Non-verifiability of investments implies contractual incompleteness that restricts the parties' options to a choice between integration (Int) and non-integration (NInt). Under the integration option, D owns the product of I's effort.[2] Consequently, I does not enjoy any of the value created by her efforts, and is motivated to invest only by the soft incentives created within the integrated firm.[3] Let $i^{Int} = \hat{i}$ denote I's investment under integration. D's investment under integration is given by: $d^{Int} = \arg\max_d \langle V(\hat{i},d) - d\rangle$. Total net payoffs under integration are: $\Pi\left(i^{Int}, d^{Int}\right) = V\left(i^{Int}, d^{Int}\right) - i^{Int} - d^{Int}$.

The second alternative is non-integration (NInt), whereby I retains control over her invention, and can sell it to D ex post. The non-integration option, however, is not always available. Given the disclosure paradox, the NInt option is feasible only if the law recognizes the product of I's efforts as intellectual property, thus affording it legal protection. If such IP protection is granted, ex post the parties will negotiate a transfer of the legal rights from I to D. Assuming Nash bargaining, the ex post surplus $V(i,d) - v^I(i) - v^D(d)$ is equally divided between the parties. Hence, I's ex post payoff is $\pi^I(i,d) = v^I(i) + \frac{1}{2}\left[V(i,d) - v^I(i) - v^D(d)\right]$, and D's ex post payoff is $\pi^D(i,d) = v^D(d) + \frac{1}{2}\left[V(i,d) - v^I(i) - v^D(d)\right]$. The investment levels are given by: $i^{NInt} = \arg\max_i \langle \pi^I(i,d) - i\rangle$ and $d^{NInt} = \arg\max_d \langle \pi^D(i,d) - d\rangle$. We assume the existence of a unique equilibrium $\left(i^{NInt}, d^{NInt}\right)$. Total net payoffs under integration are: $\Pi\left(i^{NInt}, d^{NInt}\right) = V\left(i^{NInt}, d^{NInt}\right) - i^{NInt} - d^{NInt}$.

We can now state the following:

Proposition: When $\Pi\left(i^{NInt}, d^{NInt}\right) > \Pi\left(i^{Int}, d^{Int}\right)$, if I's invention is legally protected, then non-integration will obtain, but if I's invention is not legally protected, integration will obtain.

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[1] The PRT framework employed in this section borrows from Hart (1995) and from Aghion and Tirole (1994). A TCE model could readily be developed to capture the same effect.

[2] Theoretically, the reverse form of integration, where I owns the combined product of both parties' efforts, is also possible. Following Aghion and Tirole (1994), we choose not to focus on this form of integration, which can be ruled out if I is cash constrained.

[3] These soft incentives include the possibility of promotion/demotion (or even dismissal), increased/decreased salary and other monetary and non-monetary benefits and costs conferred by the inventor's managers and peers. See, e.g., Williamson (1975). If the value of the final output V is verifiable, then I's employment contract in the Int case can be made contingent on V, thus improving I's incentives.

An integrated firm cannot replicate the "high-powered incentives" provided under non-integration, hence $i^{NInt} > i^{Int}$ (Williamson, 1985). Accordingly, the non-integration option is more efficient when the marginal importance of I's investment is large enough relative to D's investment (Grossman and Hart, 1986). But if the law does not protect the product of I's investment, the non-integration option is precluded by the disclosure paradox, forcing the parties to integrate.[4]

More generally, the Proposition implies that if I's invention is not legally protected integration will necessarily occur, and that such integration will be inefficient when $\Pi\left(i^{NInt}, d^{NInt}\right) > \Pi\left(i^{Int}, d^{Int}\right)$. The welfare implications of this result depend on the size of the set of cases where non-integration is superior to integration. Characterizing this set of cases has been and remains the main task of the boundaries of the firm literature. The welfare loss attributed to imperfect intellectual property rights would be small, if the law would refuse to protect I's invention only when integration is the optimal organizational structure. Unfortunately, legal rules are not calibrated to the economic factors that determine the relative efficiency of integration versus non-integration. In fact, the legal distinction between protected and unprotected inventions is probably orthogonal to the economic choice between integration and non-integration.

Finally, the Proposition assumes that the integration option is always feasible. This assumption is not always valid. Specifically, when the law precludes the non-integration option and the inefficiency of forced integration is sufficiently large, the innovation project might be abandoned altogether, introducing yet another welfare cost.[5]

3. Implications

The simple model developed in Section 2 has broad implications for the structure and organization of technology-intensive industries:

1) *Basic research in commercial firms*: Significant R&D at the very fundamental level is being done within commercial firms such as IBM and Motorola. While theory does not preclude the efficiency of such integration, there is good reason to believe that basic research should not generally be integrated with commercial enterprise. The absence of legal protection for pre-patent innovation is arguably a contributing factor for the integration of such innovation within firms that specialize in development and commercialization.

2) *Research universities*: A major role of universities is to foster basic research at the pre-patent stages. For present purposes, a research university is an organization, not unlike a commercial firm, that can provide soft incentives for R&D activities that do not result in a legally protected invention. In addition, public subsidization of basic research in

[4] While straightforward non-integration and trade are precluded by the disclosure paradox, in some cases the non-integration option cannot be completely ruled out. Even in the absence of legal protection of her invention, the inventor may be able to extract some value from the developer. See Teece (1986), Anton and Yao (1994, 2002), Arora (2001), Zucker et al. (2001), and Biais and Perotti (2003). Also, in certain contexts innovators are driven by non-pecuniary motives and are thus more willing to share ideas across firm boundaries. See Lessig (2001), and Benkler (2002).

[5] Regarding the feasibility of the integration option see also Section 4 below.

universities can be understood as a response to imperfect intellectual property rights. If the law does not protect an invention, then this invention may be developed within an integrated firm, or when the inefficiency of the integration option is sufficiently large the invention might not be developed at all. Public funding may be the only way—other than extending the scope of intellectual property—to ensure the development of such inventions.

3) *R&D alliances*: In the new, technology-intensive economy R&D alliances are an increasingly common phenomenon. Given imperfect intellectual property rights, the organizational structure of an alliance must respond to problems akin to those underlying the disclosure paradox. Specifically, the two partner firms are faced with a choice between a contract joint venture, where the object of the alliance becomes the subject of an explicit contract, and an equity joint venture, where the two partner firms incorporate a separate entity that will conduct R&D activities. When the law does not protect the stage of the inventive process that is the subject of the alliance, the partner firms might be forced to choose a less efficient equity structure.[6]

4) *R&D financing*: The disclosure paradox that plagues the relationship between potential sellers and buyers of pre-patent inventions might also prevent efficient external financing of the pre-patent stages of the inventive process (see Aghion and Tirole, 1994). Excessive integration to enable internal financing might follow. More generally the locus of innovation might inefficiently shift to larger firms capable of internal financing.

4. Employee Mobility

As argued above, intellectual property law affects the viability of the market option, thus influencing the boundary between firm and market. But the market option is not the only organizational form affected by the law. The viability of the firm, as an alternative to the market, also depends on the law's willingness to protect intangible assets.

Under the PRT, a firm is a collection of assets over which a manager enjoys residual control rights. Specifically, the firm controls employees' access to and use of its assets (Hart, 1995). With traditional, tangible assets unauthorized use can be easily prevented by restricting physical access to the asset. With intangible assets, however, control of access to the asset is often meaningless. When an employee, through initial access, acquires certain knowledge, denial of future access will not erase this knowledge. Access control is thus powerless to prevent unauthorized use, specifically use by the employee after she moves to another firm. If the law does not protect the intangible asset, the firm loses all control over the asset; and, in essence, the knowledge ceases to be the firm's asset.[7]

[6] The implications of weak intellectual property rights for the organization of R&D alliances have been previously recognized. See Oxley (1997, 1999), Anand and Khanna (2000), Sampson (2004), Majewski and Williamson (2003).

[7] In fact, legal protection is also a prerequisite for tangible assets. The firm's ability to restrict physical access to tangible assets relies on the law's recognition of property rights in these assets.

Patent law provides one channel for protecting intangible assets. Kim and Marschke (2001) argue that firms patent to reduce the incidence of employees leaving to start or join rival firms (see also Merges, 1999). But not all intangible assets qualify for patent protection, and some lack the minimal degree of verifiability necessary for patent protection. The law provides alternative channels for controlling the use of intangible assets by employees. Trade secret law is one such channel (Merges et al., 2003). Another channel focuses on direct limitations on employee mobility, through the law governing non-compete clauses. See Aghion and Tirole (1994), Gilson (1999), Baccara and Razin (2002), Hellmann (2002) and Burk (2004).

The theory of the firm literature presumes the viability of both the market option and the firm alternative, and proceeds to study the optimal choice between these two options. The viability of both options, however, depends on the law's willingness to recognize property rights in intangibles. Sections 2 and 3 argued that without such property rights innovation that should have ideally been mediated by the market would be forced into the confines of a single firm. The present section suggested that even the firm haven relies on some form of legal protection.

5. Conclusion

Intellectual property law directly affects the structure and organization of technology-intensive industries by imposing an often binding constraint on the choice between integration and non-integration. This characterization of legally determined appropriability as a constraint on organizational choice provides a simple theoretical link between the growing literature on the organization of innovation and the conventional TCE and Property Rights theories of the firm.

The predictions of our model sit well with the empirical evidence on the relationship between legal and organizational variations. Recently intellectual property law has made it easier to obtain patent protection for embryonic inventions (see, e.g., Mazzoleni and Nelson, 1998). The increasing importance of small specialty R&D firms (see, e.g., Arora and Merges, 2004), the increase in the number of university patents (described, for example, in Arora et al., 2001, sec. 10.4), and the prevalence of non-integration, non-equity research alliances and joint-ventures (see, e.g., Sampson, 2004) can be at least partially explained by the relaxation of the legal patentability requirements. Similarly, the growth of the venture capital industry arguably was stimulated by the law's increasing willingness to grant intellectual property rights to small research start-ups—the archetypal user of venture capital funding. Looking forward, our analysis, by identifying the different channels through which intellectual property law affects the boundaries between firm and market, suggests a range of testable predictions that we hope will motivate future empirical work.

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